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ACTUAL STATE OF THE MECHANIZATION OF HARVEST OF FRUITS AND VEGETABLES IN SPAIN.

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SUMMARY:
A review of the actual methods of harvest of fruits and vegetables in Spain is made. Special emphasis is given to the main horticultural Spanish crops that can be harvested by machines like green beans, green peas, broad beans, tomatoes, lettuces and chufas, as vegetables; and olives, almonds, cherries, apples, pears, apricots, etc. as fruits.

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1. INTRODUCTION.

Fruit and vegetable crops are widespread in Spain, mainly in the South and near the Mediterranean Sea, where the weather is suitable for many fruit and vegetable varieties. The fruit and vegetable area in Spain is of 3,940,115 ha (of which 2,085,000 are olive orchards) yielding to farmers a gross income of 814,777 x 10^6 pta ($\sim$ 5430 x 10^6 \$) refered to 1982.

Mechanization of horticultural crops is very generalized in those farm operations common to other crops (tillage, fertilizers, spraying). Many improvements in the mechanization of seeding and transplanting have been attained. The mechanical devices for harvesting are less generalized since a satisfactory solution for some crops has not been achieved yet.

Harvesting of fruits and vegetables has several problems: First the products to be harvested vary enourmously, secondly harvest machines should be very specific, and besides they are used only a few days a year and the cost per hour is high. These reasons plus the appearance of unemployed hand-labor caused by the economic crisis since 1974 have restrained the generalization of mechanical harvesting of fruits and vegetables. Spanish manufacturers have only been interested in making harvesters for the most widespread products (olive, potato) and the most sophisticated machines for other crops (tomato, green beans, green peas) have been imported.

Other type of problems about harvesting has also been studied in conjunction with the development and utilization of mechanical harvesters. There has been a great improvement in the selec

tion of varieties of annual crops adapted to machine harvesting. Some domestic varieties have been developed and some brought -- from the USA, specially from California where the weather is very similar to Spain,have been adapted.

The introduction of new varieties and different methods- of cultivation shows some problems, although in the last few -- years there seems to be a rapid change towards the new systems.- The small size of the orchards is a problem whereas the new irrigated areas have more suitable conditions for the industrialized systems of production.

The fruit trees are more difficult to adapt. The type of pruning given to the Spanish grapevine makes it impossible at - the present moment to harvest with the available machines, and- the harvesting of olive trees being also very difficult.

Important developments have taken place in the cleaning- and handling of harvested product and in its transport to pro-- cessing factory; these operations are quite mechanized.

2. ACTUAL STATE OF MECHANICAL HARVESTING.

Table 1 lists fruit and vegetable crops grown in Spain in an appreciable area (minimum 3000 hectars for each crop)*.

Most of Spanish manufacturers of implements have small - companies and they make machines adapted to the area in which - they are established. Imported machines come from USA, West Europe (France, Holland, Belgium, England, etc.) and the East Europe (Hungary).

Research into farm machinery in Spain is done by manufacturers, Universities and the National Institute of Agricultural Research. Large farm owners and processing factories buy machines for fruit and vegetable harvesting, depending on the crop.

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* Data from the Spanish Department of Agriculture.

The methods of harvesting the different horticultural products as well as the machinery used are described as follows:

2.1. Vegetables above ground.

Green beans. Manual harvesting was the only method used a few years ago; the cost of hand harvesting is about 50% of the total crop expenditure and it requires 1000 man-hours per hectare.

In order to accomplish mechanical harvesting, varieties with grouped ripening and little foliage are grown.

Water sprinkling and herbicide treatments should be used instead of tilling within the rows in order to avoid uneven ground.

At present, almost all the green beans grown for industry are machine harvested, existing 14 trailed and 7 selfpropelled harvesters*. All machines are imported by the processing industries which harvest with their own machines the product grown by the farmers under contract. There are 2 harvesting seasons in the different regions of Spain: beginning July-15 August in Andalucía and Valencia and 15 September-15 October in Castilla and Navarra (see Map, fig. 1).

Green beans hand-harvested in several passings yield 10-12 tonnes/ha while when machine harvested produce 6-10 t/ha.

Man salary for hand-harvesters, depended on the region, was 1600-3000 pta/day (10-20$) in 1983, a man usually harvests 120-150 kg green beans/day. The efficiency of machines is variable, being lower in the trailed than in the selfpropelled ones. The average efficiency of the trailed harvesters is 0.2-0.3 ha/hour; and the selfpropelled machines is 0.3-0.5 ha/h. In the last harvest season some time studies have given the following data: a) selfpropelled harvester with 2.85 m of work-width, 2.7 ha/day with an average working time of 12 hours a day

* Data showed in this paper are refered to March 1984. They have been provided by the Administration, manufacturers and dealers of farm machinery.

in an orchard yielding 10.5 t/ha (0.23 ha/h <> 2,36 t/h; b) self propelled harvester with 4.5 m of work-width, 3.9 ha/day with an average working time of 9 hours a day in an orchard yielding 6.1 t/ha (0.43 ha/h <> 2,64 t/h).

The green beans losses due to the use of harvesters range from 8 to 12 per cent of the crop.

A larger number of machines is not expected in the coming years because the actual number is enough to harvest all the green beans for industry and it does not seem possible to harvest by machine those for the fresh market. The old machines will be sustituted by new ones, replacing trailed by selfpropelled machines at a maximum rate of 2 or 3 each year.

Some machines have a device to put the beans into sacks and then are carried in sacks to the factory; others load the beans in a hopper and the transport is made in bulk.

Green peas. The harvest season of green peas for industry is very short (15 days) in each region in Spain; if the temperature rises over 30°C during 1 or 2 days, which usually happens in Spain after the end of May, the peas get hard and they are not apt for human consumption; the best hardness for harvesting is 100-105 measured by tenderometer. Sometimes the optimum harvesting period lasts less than 24 hours. The harvest season starts around April 15th in Andalucía and Murcia and ends by the middle of July in Navarra.

Industries own harvesting machines with a greater capacity than the needed for the grown area so as to be able to harvest all the area in a few days. Harvesters travel form South to North of Spain to work in each region.

Mechanical harvesting is performed on various methods:

- Cutting and windrowing with cutterbars usually employed for forage. Transport to the factory where there is a stationary-thresher; feeding of the stationary thresher is manual and it needs 3 to 4 times more hand-labor than the selfpropelled green-pea combines. This method is very unusual nowadays.

- Cutting and windrowing with cutterbars. Thresing with trailed pick-thresher machine and loading of peas in a hopper. At this moment there are 21 pick-thresher trailed machines in Spain, most of them are out of date and still useful because of the short period of use; the last machine of this kind was bought in 1979.

- Cutting and threshing with selfpropelled green-pea combine ; there are 13 of these machines in Spain, most of them imported from the USA.

The yield is 4-6 tonnes of peas per hectare. The trailed pick-thresher can harvest 0.25-0.35 ha/h, and the selfpropelled-combines harvest 0.4-0.7 ha/h.

Trucks carry peas to factories in water-proof boxes with salted water and ice in order to delay hardness and development-of diseases until they arrive to factories.

An expansion of this crop in Spain is not expected because the weather in other European countries (England, North of -- France, Hungary) is more suitable for green peas. For this reason, it is expected only the sustitution of the actual machines-by selfpropelled harvesters at a rate of 4-5 new machines per -- year.

Broad beans. The most usual method is hand-harvesting - of the pods. In some farms the pea harvesters are used, adapted-to broad beans. The average yield is 12-20 tonnes of broad beans pods per hectare.

If the beans are threshed, their carriage is made in -- bulk with water and ice. The carriage of the pods is in bulk also.

The performance of the few machines employed in broad-bean harvesting is a little bit lower that the performance on green peas.

Tomato for industry. A selection of varieties of this product has been done in order to get a better adaptation to the Spanish local conditions.

The harvest season in each region may go on for 40-50 days; the whole season, depending on the region, goes from the beginning of August till October. The harvest method has only 2 possibilites:

- Hand-harvesting, putting the tomatoes into boxes of 20-25 kg and charging them in bins of 500 kg to be carried to the factory.

- Mechanized with selfpropelled tomato harvester.

There are in total 15 tomato harvesters in Spain, all of them imported from California, with manual sorting (only one of them has optical sorting). Most of the tomato harvesters were bought around 1974-75 when hand labor was scarce but, after that time there is unemployed hand-labor and some machines are used only a few days a year; the last machine was bought in 1980. When the present economic problems are solved and Spain becomes a member of the European Common Market, at least 30 tomato harvesters are expected to be available.

The optimum size of the machines for Spanish conditions will be smaller than those machines manufactured now in California.

Nowadays the medium yield is 40-60 t/ha. A tomato harvester can harvest 0.3 -0.4 ha/h and an average of 70% of the tomato produced in the field arrives in good condition to the processing factory. Tomatoes are carried to the factory on trucks in bulk, or in 500 kg capacity bins.

Lettuce. At present there are 2 harvesting methods:

- Manual. The workers cut the lettuces, trim the stump of outer leaves, wrap them in celophane and the lettuces, depending on the sizes, are put into boxes with a capacity for 12, 15-18, 24 or 30 lettuces. Later, the boxes are charged on the trailer.

- Semimechanized. The device to help the hand harvesting is the same as the machines used in California and consists of a frame mounted on a truck in which 2 moving bands go to the sides with 5 selections posts in each side; the machine moves forward very slowly (~150 m/h) in the field of lettuces. Some workers are walking behind the lateral, they cut the lettuce and put them on the bands, the women located in the selection posts trim the stump and wrap them in celophane. The wrapped lettuces arrive to the central platform where they are put into boxes. There are 8 machines of this type in Tarragona (Mediterranean Coast); a team of 27 workers and the machine have a performance of 5000-7000 lettuces/hour (~1 ha/day). 1 or 2 passes are given in each field.

Spinach for industry. Spinach has been traditionally grown in family orchards and it is hand-harvested. In some farms it is grown in larger areas, for freezing industries or for canning and it is machine-harvested.

The harvesting machine is composed by a cutterbar, a picker-auger cylinder and a conveyor band to charge the leaves in a hopper. This harvester is tractor trailed; 2 or 3 operators are needed and it has a performance of 0.7-1 ha/h.

There is also a set of 2 machines, the first one cuts and windrows the spinaches and the second one picks them up and has an elevator to load them on a hopper.

Peppers. Peppers are grown for 3 different purposes: fresh market (green or red), sweet pepper for processing, and paprika.

Peppers for fresh market are hand harvested with 4-6 passings during the season. They are carried in plastic boxes on -- trailer or truck.

Sweet pepper is, at present, han harvested. There is a research program for finding new varieties adapted to direct seeding and mechanical harvesting and, perhaps, in the near future it will be possible to have varieties and machines for mechanical harvesting. The carriage is in bulk on trucks to the processing factory.

Pepper for paprika is almost totally hand-harvested. There are two machines, one is Hungarian and the other Spanish, which -- perform the harvesting with a picking reel while the plants remain rooted in the ground. These machines are not much employed because it would be more suitable to harvest direct seeded peppers what is not done at present.

Sweet corn. This product was unknown in Spain until 2 or 3 years ago when it was started to be grown. There is 1 combine harvester purchased by a canning industry and it is expected an increase in the land under this crop, when more processing companies -- should start to handle it. The expansion of the cultivated area -- will develop in parallel to the acquisition of more machines in -- the international market because there will not be competitive hand harvesting.

2.2. Vegetables below ground.

Although the kind of product to be harvested may be diverse (roots, bulbs, tubers, stalks), their common position below --- ground allows some polyvalence to the harvesting machines.

A general characteristics in the mechanical harvesting of vegetables below ground is the presence of machines to perform -- one single operation (lifting, picking-up, cleaning), and combine harvesters which perform several or all of the harvesting opera-- tions.

Potato. It is the vegetable below ground in which mechani cal harvesting is more generalized. There are a lot of machines - to perform one or several harvesting steps, mainly:

Strippers to strike out the stalk and leaves; there are - models turning around an horizontal or vertical axle; nevertheless, it is more usual to eliminate the aerial part by chemical methods.

Diggers which leave the potatoes either mixed with clods- or more or less cleaned in a row. There are around 15000 machines of this kind in Spain.

Potato harvesters which lift the potatoes, clean them -- from clods and stones and load them on hopper. Most of these ma-- chines in Spain are trailed and their number is around 1000 units.

Diggers work in 1 or 2 rows, the performance is 1-2 ha/day. The combine harvesters work in 1 row with a smaller performance -- (1 ha/d). About 2-2,5% of potatoes are damaged.

Potatoes lifted by a digger are usually hand-picked and -- put into sacks for transport; the transport of those harvested by potato harvester is either in bulk or in sacks also.

Carrot. Only in the small-size fields harvesting is made - by hand or by lifting with a flat blade.

There are the following kinds of machines for carrot har- vesting:

- Rotary flailer: they have some belts turning around an horizontal axle to hit the leaves removing them from the root.

- Diggers: a blade passes under the carrots lifting them with loose soil which is separated by sieving. The carrots may be put windrowed on the soil or elevated to a device to put them into sacks.

- Carrot harvesters: two belts running together hold the carrots by their leaves while a blade loose the soil and help to-lift the carrots; when the carrots are elevated to the top posi--tion, a mechanism cut the leaves, and the roots are charged on a-trailer running parallel to the machine.

Onion. It is still hand-harvested in most of the Spanish farms. Before lifting, in some regions (Catalonia) farmers use -- stripper to cut the above ground leaves.

Between the lifting (mechanical or manual) and the picking up, onions are usually left 2 to 4 days on the field to reduce moisture.

Diggers are use, the same or very similar to those used - with potatoes, suitably adapted to onion digging.

There are two kinds of diggers specially designed for onion harvesting; the first one has a horizontal flat blade of 1-1,5 m - wide which goes under the soil surface 3-5 cm deep; the second one is to work on several rows 15 cm apart and performs the digging and lifting; there is a sieving to detach the clods and the onions are left in windrows.

The picking machines for lifted and windrowed onions have a foam cylinder of 1 m in diameter, 1,5 m large with a set of long fingers below, placed in longitudinal direction; the cylinder turns

over the windrow of onions forcing them to go up on the fingers to an elevator band in which the soil falls down and 4 to 6 workers make a manual sorting and put the onions on boxes of 300 kg placed in the rear part of the machine.

Chufa (Cyperus esculentus, L.). This typical crop in the Valencia region gives small tubercles 1 cm long: the tubercles are processed to obtain a refreshing drink: "orgeat". The grown-surface is small (about 1000 ha), with an average total production of 10,000 tonnes of tubercles.

The harvest is made by hand with the help of some small-implements in several steps: 1) strike out of the aerial part of the plant, by flaming, stripping or by hand with tools; 2) loosening off the tubercles and soil by the means of a rotary tiller with small rods in the place of the curved knives to avoid damage to the tubercles; 3) picking-up the loose soil and the tubercles in baskets to screen them with mechanical driven sieves and further washing off the tubercles. All these steps need more than 1000 man-hours per hectare.

Three prototypes of harvesting machines which perform simultaneously the works of rotary tillage, picking-up and sieving have been tested, but they have not become popular because of the small size of the fields (usually less than 1 ha) in which this crop is grown.

2.3. Fruits and nuts.

Improvements of the harvesting methods in Spain of fruits and nuts have followed two ways:

- Organization of the manual works with mechanical implements to help the hand harvesting.

- Mechanization of the detachment and picking, when it is possible to hit the fruit without a serious damage.

The machines are useful for most of the crops without differences or with only a few changes to harvest different fruits;- the yearly number of hours of use is so increased.

Olives. Most of the Spanish olive fruits are for oil, and - less than 10% are for table olives. Traditionally, oil olives have been harvested by beating the branches with sticks, and table olives by hand-stripping.

After testing several harvesting methods, in the middle of the 70's multidirectional trunk shakers started to be used to detach the fruits; we had to adapt the trunk shakers to the conditions of Spanish olive trees: thick and tortuous trunk, hanging branches almost arriving to the soil and most of the olive trees with 2 or 3 trunks. At present, there exist the following machines and harvest methods:

- Multidirectional trunk shakers assembled in the front or lateral side of 65 kW or higher powered tractors. There are about- 1000 units manufactured by 4 companies in Andalucía. The number of shaking directions is in the range between 30 and 90 and the frequency between 1400 and 1800 r/min depending on the models; the -- peak to peak displacement in the point of attachment to the trunk is 15-40 mm.

The harvesting equipment is usually composed of 1 shaker, 10 to 12 workers to place the catching canvas on the soil and 1 - trailer. The workers place the 2 canvas (6 x 10 or 6 x 12 m) under the olive trees, pick-up the fallen olive fruits and charge them- on the trailer with such a rate that the shaker always finds a - tree with the canvas ready to collect the fruits. During the shaking period (10-20 seconds), 2 more workers hit the hanging bran-- ches to get a better detachment of olives in these branches, the

average detachment is more than 90%. With this method it is possible to harvest 100-200 trees a day (1-2 ha/d) and it is more-economical than the traditional method if the production per -- tree is 12 kg or more.

- Picking trailers.There are 2 kinds of trailers with - canvas in the laterals, which are more used for almonds harvesting and very little for olive harvesting. In both models, 2 -- men unroll the 2 canvas pulling from the end and the collecting, after the olives have fallen, is made mechanically. One of the-trailers has rigid canvas with strias to force the olive fruits go from the soil level to the trailer during collecting, this-trailer is 12 m long and very difficult to handle. The other -- model is shorter (7 m long) and has flexible canvas and the men which unroll each canvas should help the olives ascend till the trailer during collecting.

The olive fruits are carried in bulk till a sieve pla-- ced in the field to clean the leaves, and after that they are - carried to the olive mill.

Although less employed, there are also sweepers and -- pickers (three equipments from California) to collect the oli-- ves from the soil; the orchards which employ this method have a washing machine to clean the olives from stones and clods with a water stream.

All these machines and systems are employed in large -- orchards (more than 4000 trees) of olives for oil. Green table olives are all still hand harvested although promising tests have been made with shakers and carriage of the green olives with water and salt to avoid damage (20-30% of fruits arrive to the-processing factory with some damage).

The surface grown with olive trees in Spain will decrease in the next years, because some orchards are not economically

viable and impossible to mechanize. At present there are excedent stocks of olive oil (463.000 tonnes at the end of the 1983 season).

Almonds. The traditonal harvesting by beating the bran-- ches is being partially substituted by trunk shakers.

The same shakers that are used for olive harvesting are - employed for almonds, regulated to give a small number of shaking directions and less speed of the eccentric weights (1000-1200 r/ min). Some shakers, purchased by almond growers, work only for 20 -30 days a year, others are rented by olive growers and their utilization rises up to 100 days a year. The total number of shakers employed per almond harvesting is 60 to 70 units.

In almond orchards the smaller model of trailer with flexible canvas is widely used, either working with shakers or beating the branches with sticks.

The most mechanized equipments are composed of 1 shaker- and 2 trailers; the shaker goes between 2 rows of trees and the - trailers in the opposite side of each row; the shaker shakes alternatively one tree of each row. This equipment can harvest 300 - almond trees/day with a efficiency over 95% .

Cherries. Tests for mechanical harvesting of fresh-market cherries have given poor results because of the large amount of - damage fruits. Table cherries are still hand-harvested.

Cherries for industry are still hand-harvested mainly, because of the small size of the orchards in terraces of the side- hills in which they are grown. Mechanical harvesting with shakers has been tested and, although it has been successful, this- technic has not been adopted by the small farmers.

Mechanical harvesting with trunk shakers has the following steps:

- Spreading canvas under the tree.

- Shaking during 8-10 seconds, in this time 93% or more of the cherry fruits are detached.

- Putting of cherries into large containers with a solution of KSO_3H, $CaCl_2$ and citric acid.

After processing, cherries harvested by this method do not show any damage.

Deciduous fruits. Harvesting with shaker of fruits for industry (apples for cider, apricots for jam, etc.) is still under experimentation without great attention on the side of farmers or industries.

Harvesting of apples, pears, peaches, etc. is made by hand with the aid of ladders in orchards of isolated trees, but there are also individual selfpropelled platforms (about 80 units mainly in Catalonia to aid the picker in his movements).

Multiple platforms of continuous movement are becoming popular for fresh-market fruits when trees are in hedgerows; the platforms run slowly between two rows with workers in both sides to pick fruits in one side of each row. The primitive platforms were tractor-trailed and there are around 250 of them working in Spain. The latest models are selfpropelled and the picking places are hydraulically operated, to let workers be more or less closer to the trees row. The most automatized model is of Dutch origin; it has 3 workers in each side at different levels and a moving band to carry the fruit from each picker place to the front box of 300 kg capacity; about 60 units of this model are working at present in Spain. Another selfpropelled model made in Spain has 4 picker places in each side of the platform and the workers put the fruit in the boxes on the central part of the platform, the boxes are pushed to the rear part while they are becoming full of fruit and placed on the ground; some 40 of these units are working at present.

3. CONCLUSIONS.

The level of mechanical harvesting of fruits and vegetables in Spain has been stabilized for about the past 10 years because there is more hand-labor available in agriculture.

Besides widely mechanized and internationally competitive orchards, there are small and medium-sized orchards with an important role in the production of fruits and vegetables in Spain, which may become very competitive if they are organized in cooperatives. These small and medium-sized orchards are less efficiently mechanized with small machines; they introduce large machines only if it is possible to share their use among several farmers.

When Spain becomes a member of the European Common Market in the near future, it will be easier to mechanize more efficiently the Spanish Agriculture, with a promising future for fruits and vegetables. In any case, it will be necessary to adapt the machines for those crops to our field structures.

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Fig. 1.- Regions of Spain mentioned in the paper.

Table 1. Horticultural crops and their production in Spain (1982).

Crop	Surface (ha)	Production (tonnes)	Value in the field (millions pta)	Value in the field (millions U.S.$)
Vegetables above ground				
Green beans	25,600	247,600	18,074	120
Green peas	10,400	49,500	3,564	24
Broad beans	15,400	130,200	4,166	28
Tomato				
-industry	14,000	700,000	4,963	33
-fresh market	45,200	1,556,800	32,501	217
Lettuce	22,400	526,100	9,469	63
Spinach	3,300	54,100	1,298	9
Pepper	27,600	579,400	16,223	108
Cabbage	17,800	469,700	8,924	59
Water melon	29,300	552,800	8,292	55
Melon	66,500	850,800	19,568	130
Squash	5,900	145,700	2,769	18
Cucumber	6,200	274,900	6,872	46
Eggplant	4,700	123,400	3,578	24
Artichoke	22,800	257,000	8,481	57
Cauliflower	9,600	231,200	4,624	31
Vegetables below ground				
Potato	338,277	5,221,769	104,436	696
Carrot	5,135	145,570	2,328	16
Onion	34,300	1,051,000	13,663	91
Chufa	1,182	11,785	494	3
Garlic	37,700	201,200	25,150	168
Asparagus	15,600	49,600	9,500	63
Fruits and nuts				
Olive	2,085,000	3,338,000	93,464	623
Almond	567,700	315,300	18,918	126

Crop	Surface (ha)	Production (tonnes)	Value in the field (millions pta)	Value in the field (millions U.S. $)
Cherry	16,300	72,400	6,226	42
Orange	127,700	1.687,400	33',748	225
Mandarin	52,000	879,100	21,977	147
Lemon	46,900	429,500	6,013	40
Apple	61,900	891,700	19,617	131
Pear	36,600	450,500	15,767	105
Apricot	21,900	180,500	4,693	31
Peach	50,800	470,100	23,505	157
Plumb	16,800	112,200	3,306	22
Fig	22,100	48,400	1,452	10
Hazelnut	36,800	19,500	2,242	15
Banana	13,600	455,200	15,021	100